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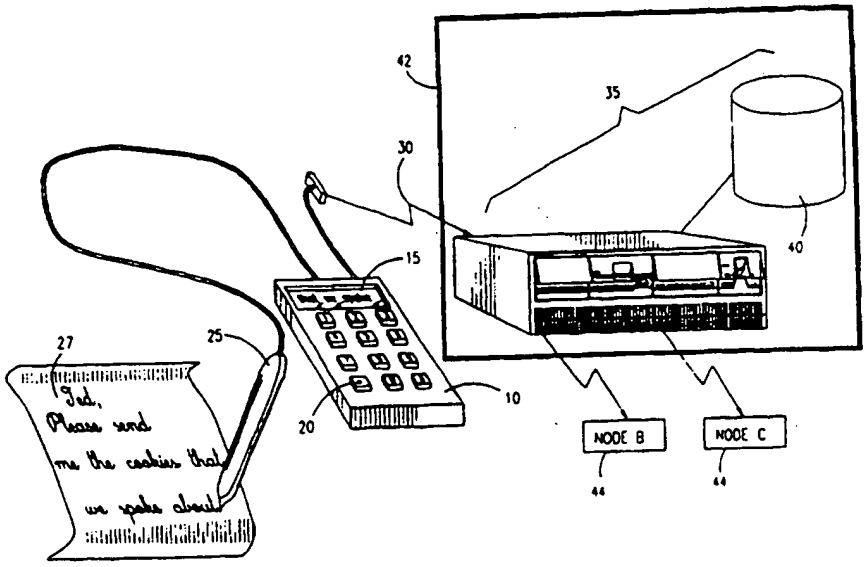

(57) Abstract

This invention discloses a secure computer system including at least one node connected to a communications network and a pen inpu device providing an output to the at least one node, the node including handwriting recognition apparatus operative to receive the output c the pen and during substantially the entire duration of the data input from the pen to convert the output of the pen into writing character by recognizing the characteristics of the handwriting of a user of the pen and comparing the characteristics with reference characteristic whereby successful communication is conditional on successful conversion of the output of the pen into writing characters.

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CONTINUOUS SECURITY SYSTEM BASED ON MOTION CODE

The present invention relates to secure computer systems in general.

There exists a significant amount of activity in the field of on-line handwriting analysis. The prior art current to 1990 is reviewed in "The State of the Art in On-Line Handwriting Recognition" by Charles C. Tappert et al, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 12, No. 8, August, 1990.

Currently existing and proposed systems providing handwriting analysis for alphanumeric input to a computer are generally geared towards recognition of how the generated trace looks. Accordingly, such systems employ digitizers or graphic tablets. The underlying assumption of such systems is that the variability of the trace is much lower than the variability of the hand movement which generated the trace.

Signature verification systems, on the other hand, attempt to identify biometric characteristics of the writer and employ indications such as pressure and acceleration during writing. The assumption is that the signature is a ballistic movement, that is, a movement without closed loop feedback, and therefore that there is little variance in the hand movement.

U.S. Patent 4,345,239 employs pen acceleration for use in a signature verification system. U.S. Patent 5,054,088 employs both acceleration and pressure data characteristics of signature verification. As indicated by the above patents, pen acceleration is employed for signature verification because it is a personal feature, characteristic of each individual.

U.S. Patent 4,817,034 describes a computerized handwriting duplication system employing a digitizer pad.

U.S. Patent 4,641,354 describes apparatus for recognizing and displaying handwritten characters and figures in which unrecognized stroke information remains on the display screen. U.S. Patent 4,715,102 describes a process and apparatus involving pattern recognition. U.S. Patent 4,727,588 describes a system for automatic adjustment and editing of a handwritten text image, which preserves format information in a handwritten text. U.S. Patent 4,703,511 describes a writing input and dynamics regeneration device wherein a time dependent code is embedded in a writing path.

U.S. Patent 4,513,437 describes a writing implement for use in a signature verification system.

U.S. Patent 5,054,088 describes a method of segmenting and compressing dynamic signature data for storage on a limited capacity device.

U.S. Patent 4,856,077 describes a method and device for signature verification using a pen having at its nib a light-emitting member and a light-sensitive member.

U.S. Patent 4,495,644 describes a method for real-time signature verification using a transducer pad and a stylus.

U.S. Patent 4,345,239 describes apparatus for determining pen acceleration for use in a signature verification system.

U.S. Patent 4,263,592 describes an input pen usable with either a CRT display or a tablet input device.

U.S. Patent 4,122,435 describes a method for producing an electrical signal responsive to identifying characteristics of handwriting. The electrical signal is produced responsive to variations in writing pressure between a writing instrument and a ridged writing surface.

U.S. Patent 4,751,741 describes pen-type char-

acter recognition apparatus, using data representing a change in pressure applied to a tip element of a pen.

U.S. Patent 5,022,086 describes apparatus for collecting information on handwriting using a stylus with means for sensing force at a point on the surface, together with a position sensing pad.

U.S. Patent 5,247,137 discloses a pen input device suitable for signature verification.

A piezoelectric sensor pen for obtaining pen point dynamics during writing is described in EerNisse et al., "Piezoelectric Sensor Pen for Dynamic Signature Verification", Conference of the 1977 International Electron Devices Meeting, Washington, DC, December 1977, pp. 473-476.

A related apparatus for reading handwriting is described in published PCT application PCT/US92/08703. Related apparatus and methods are also described in the following pending applications assigned to the applicant of the present application: Israel 104575; Israel 108566; United States 08/227,275; and United States 08/380,068.

The disclosures of the above publications and of the publications cited therein are hereby incorporated by reference. The disclosures of all publications mentioned in this specification and of the publications cited therein are hereby incorporated by reference.

The present invention seeks to provide an improved secure computer system.

The secure computer systems known in the art rely on identifying the user once or at specific times, and not continuously. Furthermore, existing secure systems need to take some action in order to achieve the identification of the user, for example, verifying a password, a fingerprint, etc. It is a particular object of the present invention to provide continuous security via continuous handwriting recognition without taking any

specific action for identification.

Continuous security is believed to be important because of the increasingly widespread use of communications networks, such as the Internet, in which secure communications are believed to be of great importance in preventing misuse. Continuous security has the particular advantage of protecting a communications session at all times, thus preventing unauthorized use of an already-authorized session.

Furthermore, the present invention includes continuous security by means of input from a pen, the input including characteristics of handwriting of the user of the pen. The continuous security of the present invention is thus based on a biometric characteristic and, unlike a PIN or password, is not based on something known by a user, but rather on characteristics of the user himself. The prior art, as discussed above, does describe security based on identity verification by means of verifying the signature but does not describe continuous security based on handwriting recognition in general. The present invention, by contrast, includes continuous security based on general handwriting recognition.

There is thus provided in accordance with a preferred embodiment of the present invention a secure computer system including at least one node connected to a communications network, and a pen input device providing an output to the at least one node, the node including handwriting recognition apparatus operative to receive the output of the pen and during substantially the entire duration of the data input from the pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of the pen and comparing the characteristics with reference characteristics, whereby successful communication is conditional on successful conversion of the output of the pen into writing characters.

There is also provided in accordance with another preferred embodiment of the present invention a secure computer communications system including a communications network, at least one terminal coupled to the communications network, at least one server coupled to the communications network, and a pen input device communicating via the at least one terminal with the server, and wherein the server includes handwriting recognition apparatus operative to receive the output of the pen and during substantially the entire duration of the data input from the pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of the pen and comparing them with reference characteristics, whereby successful communication of information via the server is conditional on successful conversion of the output of the pen into writing characters.

Further in accordance with a preferred embodiment of the present invention communication from the pen input device to the server is secure by virtue of the communication being unintelligible in the absence of the availability of the reference characteristics.

Still further in accordance with a preferred embodiment of the present invention the server is located in a secure location.

Additionally in accordance with a preferred embodiment of the present invention the pen input device includes an accelerometer and provides accelerometer output signals to the terminal.

Moreover in accordance with a preferred embodiment of the present invention the at least one terminal includes a display and is operative to provide visible indication of recognized symbols in response to an input from the server.

Further in accordance with a preferred embodiment of the present invention the at least one terminal

includes a keyboard for the input of function commands.

Still further in accordance with a preferred embodiment of the present invention information input by the pen input device, when and only when successfully recognized, is communicated to a utilization device.

Additionally in accordance with a preferred embodiment of the present invention the characteristics of the handwriting of the user include a mapping of hand movements, and the reference characteristics include a reference mapping of hand movements for the user.

Moreover in accordance with a preferred embodiment of the present invention the reference mapping includes a mapping of hand movements to characters for the user.

Further in accordance with a preferred embodiment of the present invention the successful communication is not conditional on any other user input in order to achieve security.

Still further in accordance with a preferred embodiment of the present invention the successful communication is not conditional on use of any additional system resources in order to achieve security.

There is also provided in accordance with another preferred embodiment of the present invention a method for providing a secure computer system, the method including providing at least one node connected to a communications network, and providing a pen input device providing an output to the at least one node, the node including handwriting recognition apparatus operative to receive the output of the pen and during substantially the entire duration of the data input from the pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of the pen and comparing the characteristics with reference characteristics, whereby successful communication is conditional on successful conversion of the

output of the pen into writing characters.

There is also provided in accordance with another preferred embodiment of the present invention a method for providing a secure computer communications system, the method including providing a communications network, providing at least one terminal coupled to the communications network, providing at least one server coupled to the communications network, and providing a pen input device communicating via the at least one terminal with the server, and wherein the server includes handwriting recognition apparatus operative to receive the output of the pen and during substantially the entire duration of the data input from the pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of the pen and comparing them with reference characteristics, whereby successful communication of information via the server is conditional on successful conversion of the output of the pen into writing characters.

The present invention will be understood and appreciated from the following detailed description, taken in conjunction with the drawings in which:

Fig. 1 is a simplified pictorial illustration of a secure computer system constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 2 is a simplified block diagram illustration of a preferred embodiment of a portion of the apparatus of Fig. 1;

Fig. 3 is a schematic diagram of a preferred embodiment of the apparatus of Fig. 2;

Fig. 4 is a simplified pictorial illustration of a preferred embodiment of the pen 25 of Fig. 1;

Figs. 5A and 5B are a pictorial illustration of a preferred implementation of the switch 85 of Fig. 4;

Fig. 6 is a schematic diagram of a preferred

implementation of the printed circuit board 105 of Fig. 4;

Fig. 7A is a simplified block diagram illustration of a preferred implementation of the server 35 of Fig. 1;

Fig. 7B is a simplified flowchart illustration of a preferred method of a portion of the operation of the control module 240 of Fig. 7A; and

Fig. 8 is a simplified flowchart illustration of a preferred method of operation of the handwriting recognition module 210 of Fig. 7A.

Attached to the end of the specification are the following appendices which aid in the understanding and appreciation of one preferred embodiment of the invention shown and described herein:

Appendix A is a specification listing useful in understanding the apparatus of Fig. 4;

Appendix B is a netlist of the apparatus of Fig. 6; and

Appendix C is a part list of the apparatus of Fig. 6.

Reference is now made to Fig. 1 which is a simplified pictorial illustration of a secure computer system constructed and operative in accordance with a preferred embodiment of the present invention. The system of Fig. 1 comprises a terminal 10. The terminal 10 preferably comprises a display screen 15 and a plurality of data input keys 20. Preferably, the terminal 10 is sufficiently small to be portable.

The terminal 10 is described in more detail below with reference to Fig. 2.

The terminal 10 is operatively attached to a movement-sensing pen 25, operative to write on any appropriate surface such as a sheet of paper 27. The pen 25 is described in more detail below with reference to Fig. 4.

The pen 25 and the terminal 10 are shown in Fig. 1 as being operatively attached via a cable, but it is appreciated that any appropriate method of attachment as, for example, wireless communication, may be used.

The terminal 10 comprises data communication apparatus (not shown in Fig. 1) which is operative to provide a data communication connection 30 to a server 35. As shown in Fig. 1, the data communication connection 30 is a remote data communication connection and may be any appropriate remote data connection such as, for example, a modem connection over switched telephone line or a modem connection over a dedicated telephone line. Alternatively, the data communication connection 30 may be a local connection and the server 35 may be located locally to the terminal 10.

The server 35 may be any appropriately programmed computer.

The server 35 comprises a handwriting recognition database 40. The handwriting recognition database 40 comprises a per-person, per-symbol database identifying handwriting characteristics for each of a plurality of persons, and, for each person, for each of a plurality of symbols. The per-person, per-symbol database is described in more detail below with reference to Fig. 8.

In a preferred embodiment of the present invention, the server 35 is located in a secure location 42. The secure location 42 restricts access to the server 35 and thus enhances security with the system of Fig. 1 by preventing tampering with the database 40 or with other aspects of the server 35.

The system of Fig. 1 also preferably comprises other nodes 44 which, together with the terminal 10 and the server 35, comprise nodes of a communications network.

The operation of the apparatus of Fig. 1 is now briefly described. A user establishes a connection with

the server 35 through the terminal 10, using the data input keys 20 for data entry. Establishing a connection includes providing the identity of the user, typically by entering a personal identification number (PIN) using the data input keys 20. It is appreciated than any means of providing the identity of the user may be employed, such as, for example, the following means which are well-known in the art: signature recognition; electronic key or electronic card based recognition; fingerprint identification; retina identification; or any other means of identification.

The server 35 receives the connection request from the terminal 10, verifies the identity of the user, and, if the identity is verified successfully, establishes a connection with the terminal 10. Typically, the server 35 displays a message on the screen 15 indicating that a connection has been established.

Once a connection has been established, the user employs the terminal 10 and the pen 25 for data entry, which data is transmitted to the server. Typically, a combination of data entry via the data input keys 20 and via the pen 25 is employed, although it is possible to employ the pen 25 alone.

The user employs the pen 25 to write on a surface such as the paper 27. The pen 25 is operative to sense movement of the pen 25 and to transmit signals representing the movement to the terminal 10, which in turn transmits the signals via the data communication connection 30 to the server 35.

The server 35 employs handwriting recognition techniques, as described below with reference to Fig. 8. The handwriting recognition techniques employ the per-person, per-symbol database 40 to identify, for the person previously verified as the user, the most likely symbol written.

Preferably, the handwriting recognition tech-

niques also use a dictionary of words to provide word-level recognition, and linguistic analysis to recognize phrases and sentences. As the user employs the pen and as symbols are recognized by the server 35, the server 35 typically transmits the recognized symbols to the terminal 10 for display on the screen 15, to provide feedback to the user.

As described below with reference to Fig. 8, recognition is based on hand movements which are unique to a given individual. When the verified user writes with the pen 25, the server 35 recognizes the symbols written based on the per-person, per-symbol characteristics stored in the database 40.

If another person other than the verified user begins to write with the pen 25, the server 35 will not correctly recognize the symbols since the unauthorized other person will employ different hand movements than the verified user. The server 35 may make a determination that the user is unauthorized, that is, is not the verified user, based on any appropriate criteria such as, for example:

inability of the server 35 to recognize more than a minimum percentage of symbols input, which minimum percentage may vary from individual to individual and from application to application according to the security level required;

significant misrecognition determined at the word level, based on more than a maximum percentage of words that are not in the dictionary being recognized; or

any other appropriate criterion.

Alternatively, since the server 35 will not correctly recognize the symbols written by the unauthorized person, the system will ipso facto cease to operate in response to pen input by the user and thus no determination by the server 35 is necessary.

It is appreciated that the various functions

assigned above to the server 35 may alternatively be performed within the terminal 10, in which case the various elements of the server 35 would be incorporated into the terminal 10. Further alternatively, it is appreciated that the pen 25 may be located locally to the server 35 and may be directly connected thereto without use of a terminal 20 or a communication link 30.

Reference is now made to Fig. 2, which is a simplified block diagram illustration of a preferred embodiment of a portion of the apparatus of Fig. 1. The apparatus of Fig. 2 comprises the terminal 10 of Fig. 1.

The apparatus of Fig. 2 comprises the display 15, comprising a display subsystem such as, for example, a PC0024-A LCD module, commercially available from Powertip Technology Corporation, N^{o} 18 - 3 Nan 2nd Rd. T.E.P.Z., Tanzu, Taichung, Hsien, Taiwan, R.O.C. It is appreciated that another display subsystem, such as a subsystem with graphics capability, may also be used.

The apparatus of Fig. 2 also comprises the data input keys 20, comprising a keyboard module such as, for example, a 88BB2-072 keyboard 4 x 4 matrix module, commercially available from Grayhill, Inc., 561 Hillgrove Ave., La Grange IL 60525-0373, USA.

The apparatus of Fig. 2 also comprises a pen interface module 45, which is operative to provide an electronic data connection between the terminal 10 and the pen 25. The pen interface module 45 may be any suitable interface as, for example, a commercially available RS-232 interface with associated line driver.

The apparatus of Fig. 2 further comprises a microcontroller 50 which is operative to control operations of the terminal 10 and to control two-way communications with the server 35. The microcontroller may be any suitable microcontroller such as, for example, a PIC17C42 high-performance 8 bit EPROM microcontroller, commercially available from Microchip Technology Inc.,

2311 West Chandler Blvd., Chandler, AZ 85224-6199, USA.

The apparatus of Fig. 2 further comprises a communication module 55, suitable to provide the data connection 30 over the medium being used for the data connection 30. In the case of a modem connection over a telephone line, a suitable communication module 55 comprises the AK14-D007-001, commercially available from Rockwell International, Digital Communication Division, 4311 Jamboree Road, P.O. Box C, Newport Beach, CA, 92658-8902, USA.

The microcontroller 50 is preferably connected to the other elements of Fig. 2 as follows:

to the display 15 via both data and control connections;

to the data input keys 20 via a data connection;

to the pen interface module 45 via a data connection; and

to the communication module 55 via both data and control connections.

Optionally, the apparatus of Fig. 3 may also comprise a memory module (not shown). In this case, the terminal 10 may be operative to store signals received from the pen 25 and/or commands received from the data input keys 20, and transmit the same at a later time. It is appreciated that, in this case, the terminal 10 may be used for standalone input and may not actually be connected to the data communication connection 30 at the time of input.

Reference is now made to Fig. 3, which is a schematic diagram of a preferred embodiment of the apparatus of Fig. 2. The diagram of Fig. 3 is self-explanatory.

Reference is now made to Fig. 4 which is a simplified pictorial illustration of a preferred embodiment of the pen 25 Fig. 1.

The apparatus of Fig. 4 comprises a top case 60, a bottom case 65, and a supporting element 70 all preferably formed of plastic. The apparatus of Fig. 4 also comprises a refill holder 75, preferably formed of plastic and shaped to hold a standard pen refill 80.

The apparatus of Fig. 4 further comprises a switch 85. The switch 85 is positioned relative to the refill holder 75 such that, when a user of the pen 10 presses the tip of the refill 80 against a surface, the refill holder 75 actuates the switch 85. The switch 85, when actuated, sends a signal to a microcontroller 100.

The switch 85 is preferably formed of silicone rubber, with key travel of 0.2 mm, activation force 20 - 30 gram, activation time less than 1 millisecond, and maximum contact resistance 500 ohm.

Reference is now additionally made to Figs. 5A and 5B, which are pictorial illustrations of a preferred implementation of the switch 85 of Fig. 4. The apparatus of Figs. 5A and 5B comprises the switch 85, the refill holder 75, and the pen refill 80. In Fig. 5A, the switch 85 is depicted in a state where the pen refill 80 is not in contact with a surface. In Fig. 5B, the switch 85 is depicted in a state where the pen refill 80 is in contact with a surface, such that the refill holder 75 actuates the switch 85.

The apparatus of Fig. 4 also comprises a 3-dimensional accelerometer 90, which is operative to sense accelerations in three mutually orthogonal directions and to output a signal representing the sensed accelerations. Taking into account optimum shaping of the pen 25 to fit the hand of a user, the accelerometer 90 is preferably located as close as possible to the tip end of the pen 25.

The accelerometer 90 may, for example, be an ACH-04-08, commercially available from AMP Sensors, Inc., P.O. Box 799, Valley Forge, PA 19482, USA, modified

according to the specifications found in Appendix A. Such modified accelerometers are commercially available from BarOn Technologies Ltd., Gutwirth Science Park, Technion City, Haifa 32000, Israel.

Alternatively, a single accelerometer or three accelerometers mounted mutually orthogonally to each other may be used.

The apparatus of Fig. 4 also includes an operational amplifier 95, such as a LMC 6464, commercially available from National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, CA 95052-8090, USA.

The microcontroller 100 preferably includes an analog-to-digital converter. An example of a suitable microcontroller is the PIC16C71, commercially available from Microchip Technology Inc., referred to above.

The apparatus of Fig. 4 also comprises a printed circuit board (PCB) 105. The switch 85, the accelerometer 90, the operational amplifier 95, and the microcontroller 100 are all mounted on the printed circuit board 105. Reference is now additionally made to Fig. 6, which is a schematic diagram of a preferred implementation of the printed circuit board 105. Reference is now also additionally made to Appendix B, which is a netlist of the apparatus of Fig. 6, and to Appendix C, which is a part list of the apparatus of Fig. 6. Fig. 6 is self-explanatory with regard to Appendices B and C.

The apparatus of Fig. 4 also comprises a cable 110, preferably having a strain relief apparatus 115, and terminating in a data connector 120. The data connector 120 may be any appropriate data connector, and is typically an RS-232 connector.

During operation, the accelerometer 90 measures movement of the pen 25 and sends signals representing the acceleration to the operational amplifier 95. The operational amplifier 95 amplifies the signals and sends them to the microcontroller 100. At the same time, the switch

85 sends signals indicating whether the refill 80 is in contact with a surface to the microcontroller 100.

The microcontroller 100 digitizes the received signals and sends digital signals through the cable 110 and connector 120. The signals preferably comprise an indication of whether the refill 80 is in contact with a surface, as indicated by the position of the switch 85. The signals also comprise movement data based on accelerations measured by the accelerometer 90. Preferably, the signals sent by the microcontroller 100 comprise approximately 100 samples per second.

Typically, the pen 25 receives electrical power through the cable 110 from the data connector 120.

It is appreciated that a particular advantage of the present invention is that continuous security by means of continuous handwriting recognition of the individual using the system may occur repeatedly or continuously during use of the system rather than occurring only at the beginning of a session. It is also appreciated that a particular advantage of the present invention is that the security criterion is based on a biometric characteristic and, unlike systems based on a PIN or password, is not based on something known by a user, but rather on characteristics of the user himself.

Reference is now made to Fig. 7A, which is a simplified block diagram illustration of a preferred implementation of the server 35 of Fig. 1. The elements of Fig. 7A comprise functional components of the server 35, and are typically implemented in software, but may be implemented in a combination of software and hardware or in hardware.

The apparatus of Fig. 7A comprises a terminal communication module 200, which is operative to transmit data in both directions between the terminal 10 of Fig. 1 and the apparatus of Fig. 7A. The data received from the terminal 10 may comprise signals representing movement or

acceleration of the pen 25; the status of contact between the pen 25 and the surface 27; and commands representing entries made on the data input keys 20.

The terminal communication module receives data to be sent to the terminal 10 from a control module 240 described below, and supplies data received from the terminal 10 to the control module 240. The terminal communication module 200 may utilize conventional methods which are well known in the art.

The apparatus of Fig. 7A also comprises a handwriting recognition module 210. The handwriting recognition module 210 has a plurality modes of operation, comprising training mode and recognition mode.

In training mode, the operation of the handwriting recognition module 210 is as follows. The user writes symbols from a pre-arranged script known to the handwriting recognition module 210, and the associated symbols appear on the display 15 of Fig. 1 during the writing. Preferably, the pre-arranged script contains several repetitions of each symbol. Preferably, based on the experience of the inventor, the symbols should occur in different parts of the word, such as beginning, middle, and end, throughout the pre-arranged script. The handwriting recognition module 210 is operative to produce the database 40 based on the movement data received during training mode.

It is appreciated that the database 40 may be produced other than in training mode. For example, the database 40 may be externally loaded into the server 35 based on a similar process of training which occurred with other equipment. The other equipment may be similar to the system of Fig. 1 or may omit the terminal 10 and comprise the pen 25 and the server 35.

In recognition mode, the operation of the handwriting recognition module 210 is as follows. The handwriting recognition module 210 receives a message

from the control 240 indicating the identity of the user. The handwriting recognition module 210 is then operative to receive signals representing movement of the pen 25 and pen-surface contact of the pen 25 with the surface 27, through the terminal 10, from the control 240.

The handwriting recognition module 210 is operative to produce text based on the received signals and to send the text to the control 240. The handwriting recognition module 210 is also operative to determine an index of likelihood for the produced text, the index of likelihood representing the likelihood that the produced text is the correct interpretation of the movements of the pen 25 which produced the received signals. The index of likelihood preferably includes an indication, such as a likelihood of 0, that handwriting can not be recognized at all, so that no meaningful text is produced. The handwriting recognition module is also operative to send the index of likelihood to the control module 240. The operation of the handwriting recognition module 210 is described more fully below with reference to Fig. 8.

As describe above with reference to Fig. 1 and below with reference to Fig. 8, it is appreciated that an attempt to use the pen 25 by a user other than the identified user of the system will lead to a very low recognition rate.

The apparatus of Fig. 7A also comprises one or more applications 230. Each application 230 may be any appropriate computer application, capable of running on the server 35, and preferably having network communication capabilities. Examples of suitable applications include the following:

electronic mail applications;

bi-directional paging and messaging applications;

network services applications, such as Internet applications; and

other applications.

Each application 230 is operative to receive text input from the control module 240, representing text produced by the handwriting recognition module 210. Each application 230 is also operative to send output to the control module 240, for forwarding through the terminal communication module 200 to the terminal 10.

The apparatus of Fig. 7A also comprises a control module 240. The control module 240 is operative as described above to send and receive data to and from the terminal communication module 200, the handwriting recognition module 210, and the applications 230.

The control module 240 is operative, when receiving data, to determine the destination of the data and to forward the data to the appropriate destination. For example, when receiving data from the terminal communication module 200 representing movement of the pen 25, the control module 240 is operative to send the data to the handwriting recognition module 210. When receiving data from the terminal communication module 200 representing a press of one or more of the data input keys 20 indicating a command sequence, the control module 240 is operative to carry out the command received.

Preferably, the control module 240 is operative to determine whether data received from the terminal communication module 200 represents movement of the pen 25 or a press of one or more of the data input keys 20 by examining the data received. For example, a particular binary or hexadecimal sequence, for example hexadecimal FF, might be used to indicate a key press in the following one or more bytes of data, while all other values ranging from hexadecimal 00 to hexadecimal FE might be used to indicate pen movement data.

The control module 240 is also operative, based

on the index of likelihood received from the handwriting recognition module 210, to determine whether the present user of the pen 25 is not the identified user.

Typically, the control module 240 is operative to make the determination that the present user is not the identified user based on a comparison of the likelihood received with a minimum likelihood criterion. Typically, the minimum likelihood criterion comprises a minimum likelihood level and minimum duration of time below said minimum likelihood level, so that a determination that the present user is not the identified user would typically be based on the likelihood level being below the minimum likelihood level for at least the minimum duration of time.

The minimum likelihood criterion may vary with respect to requirements of a particular application 230, described below, or may vary according to the identified user. The variation according to the identified user is believed to increase the level of accuracy of security achieved because some users write in a more consistent way than other users, so that the more consistent users can be expected to produce a higher index of likelihood, and hence may be assigned a higher minimum likelihood criterion, than the less consistent users.

Upon making a determination that the present user is not the identified user, the control module 240 is preferably operative to take some action to secure communications, typically to command the terminal communication module 200 to end the communication session with the terminal 10.

Reference is now made to Fig. 7B, which is a simplified flowchart illustration of a preferred method of a portion of the operation of the control module 240 of Fig. 7A. The method of Fig. 7B is a preferred method for determining whether the present user of the pen 25 is not the identified user. The method of Fig. 7B is

self-explanatory with respect to the above discussion of Fig. 7A.

Alternatively to the method described above wherein the control module 240 takes some action to secure communication, it is appreciated that, since the handwriting recognition module 210 will not correctly recognize the symbols written by the unauthorized person, the system will ipso facto cease to operate in response to pen input by the user, and no determination by the control module 240 is necessary.

Reference is now made to Fig. 8, which is a simplified flowchart illustration of a preferred method of operation of the handwriting recognition module 210 of Fig. 7A. The method of Fig. 8 preferably includes the following steps:

STEP 310: Receive accelerometer data. Accelerometer data is received from the control module 240. The accelerometer data comprises data points representing sampling of the acceleration measured by the pen 25. Preferably, the sampling rate is approximately 1600 data points per second, averaged over 16 points, producing an output of approximately 100 data points per second.

STEP 315: Identify individual symbols and words. The data from the previous step is divided into data representing individual symbols. The status which comprises the status of "pen up" is termed herein "pen not down". Preferably, the number of consecutive data points with status of "pen not down", which data points represent a particular duration of the status "pen not down", is taken to indicate the end of a symbol or of a word.

Typically, the duration of status "pen not down" within a range from 200 milliseconds to 400 milliseconds is taken to indicate the end of a symbol. Duration of the status "pen not down" in the range from 800 milliseconds to 1200 milliseconds is typically taken to

indicate the end of a word.

Alternatively, the end of a symbol or of a word may be indicated by data points which represent pen movements that are not part of a symbol, or by other means.

Further alternatively, it is possible to discern the end of a word or symbol via analysis based on a dictionary and/or on linguistic rules, similarly to the method described below with reference to step 420.

STEP 330: Filter accelerometer data. The accelerometer data received from the previous step is filtered in order to remove noise. The filtering may be accomplished by iterative smoothing of adjacent points until the total change in the signal due to a smoothing operation is less than the desired accuracy of the data, or by other suitable means.

STEP 400: For each prototype in the per-person per-symbol acceleration prototype database, build an index of comparison between the sample and the prototype.

STEP 410: Create a list of probable symbols sorted by likelihood. Based on the index of comparison generated in step 400, a single list of probable symbols sorted by likelihood is generated.

STEP 420: Choose the correct symbols and the correct word based on the list, the database of previous confusions, a dictionary, and linguistic rules. The symbols with greatest likelihood are the candidates from which the correct symbol is chosen.

The database of previous confusions provides information that allows the correction of the choice of the correct symbol based on previous incorrect identifications.

An indication of the end of each word has been passed as output since step 315, described above. Based on the indication, the most likely word, comprising the most likely identifications for each symbol in the list,

is identified.

Alternatively, an attempt may be made to find likely words, based on use of the dictionary and on applying linguistic rules as described below, without regard to data indicating the end of each word. It such a case, letters are accumulated and the accumulated letters are checked continuously in order to find the best option for a likely word. For example, if the word "slow" has already been identified in the accumulated letters, and the letters "ly" are next identified, an additional possibility is now noted that the identification of "slow" may be replaced with an identification of "slowly". If the next letter identified does not create a possible word beginning with "ly", the identification of "slowly" is preferred over the identification of "slow ly". In the case of this alternative, step 315 may be optional.

The most likely word is checked against the dictionary. Preferably, the dictionary comprises both a general dictionary used for all users of the system and a personal dictionary for each user of the system. If an entry exists in the dictionary for the most likely word, the word is chosen as the correct identification.

If the most likely word is not found in the dictionary, all possible word combinations in the list are formed and each is checked against the dictionary. Among all such words which are found in the dictionary, the word with the highest likelihood is then chosen as the correct identification.

If none of the words is found in the dictionary, the most likely word is chosen as the correct identification.

STEP 440: Update database of previous confusions. Based on a manual correction entered by the user or an automatic correction based on the dictionary and/or on the application of linguistic rules, the database of

previous confusions is updated. Based on a manual correction, the personal dictionary is also updated if the corrected word is not found in the dictionary.

STEP 450: Update per-person per-symbol acceleration prototype database. The new prototype from the previous step are stored in the per-person per-symbol acceleration prototype database.

Step 460: Output recognition information. The sorted list of likely words output by the previous step is output to the control module 240.

It is appreciated that the software components of the present invention may, if desired, be implemented in ROM (read-only memory) form. The software components may, generally, be implemented in hardware, if desired, using conventional techniques.

It is appreciated that the particular embodiment described in the Appendices is intended only to provide an extremely detailed disclosure of the present invention and is not intended to be limiting.

It is appreciated that various features of the invention which are, for clarity, described in the contexts of separate embodiments may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment may also be provided separately or in any suitable subcombination.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention is defined only by the claims that follow.

APPENDIX A

SPECIFICATION SHEET

3-Axis (X, Y, & Z) Accelerometer with JFET Impedance Buffers

		Min	Type	Max	Units
PERFORMANCE SPECIFICATIONS (T=25C)[1]					
Sensitivity[2]	• X-Axis Max Tolerance	2.25	3.00	3.75	mV/g
	• Y-Axis Max Tolerance	2.25	3.00	3.75	mV/g
	• Z-Axis Max Tolerance	1.50	2.00	2.30	mV/g
	• Within one Lot	±15% of Average Lot Value and within Max Tolerance.			
Frequency Range		---	0.5	0.7	Hz
	- 3dB	1.5	---	---	kHz
	- 3dB	6.0	---	---	kHz
Resonant Frequency		---	1.0	---	Hz/Hz
Resonant Q		---	0.1	1.0	%Reading
Linearity		1.0	---	---	g's
Dynamic Range		---	4.2	---	$mg/\sqrt{Hz}$
Noise	1Hz	---	0.7	---	$mg/\sqrt{Hz}$
	10Hz	---	0.1	---	$mg/\sqrt{Hz}$
	1,000Hz	---	10	20	%
Transverse Sensitivity		---	TBD	---	g/C
Temperature Transient Sensitivity		---	TBD	---	$g/\mu\epsilon$
Base Strain Sensitivity					
ELECTRICAL SPECIFICATIONS (T=25C)					
Gate-Drain Voltage		-30	---	---	V
Gate-Source Voltage		-30	---	---	V
Gate Current		---	---	10	mA
Power Dissipation		---	---	360	mW
Power Derating		---	3.27	---	mW/C
Gate-Source Cutoff Voltage ($V_{GS/OFF}$)		-0.5	---	-1.8	V
Saturation Drain Current (I_{DSS})**		10	---	150	μA
CA Forward Transconductance (g_{fs})**		50	---	210	μS
Outpout Impedance[3]		---	180	---	$k\Omega$

APPENDIX A CONTINUED

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature[4]	0C to +75C
Storage Temperature	-40C to +110C
Operating Relative Humidity	95% Non-Condensing
Operating Altitude	-400 to 10,000 feet
Storage Altitude	5,000 g's, any axis
Weight	0.35 Grams Typical

NOTES:

1: Reference frequency is 335Hz unless otherwise noted.

2: Assumes constant current bias, guarded Drawn 6 Source.

3: Output impedance is user selected. Type values: 180kΩ for aplit & 20 kΩ for single supply.

4: Nominal sensitivity will typically change ±5% over this range.

APPENDIX B

```
NET 'N00001' U5-3 C250-2 R157-1
NET 'N00002' R15-2 U3-4
NET 'N00003' R12-1 D1-CATHODE
NET 'N00004' R12-2 J1-3
NET 'N00005' U5-1 R159-2 C253-2 C256-1
NET 'N00006' C256-2 R22-1 TP_ICT1-1 U2-3
NET 'N00007' R155-2 Q3-BASE Q2-BASE Q1-BASE Q4-BASE
NET 'N00007' Q4-COLLECTOR
NET 'N00008' U5-2 R158-2 R159-1 C253-1
NET 'N00009' U2-1 R19-2 C22-2 R17-1
NET 'N00010' R17-2 TP_ICT4-1 U3-1
NET 'N00011' U1-2 Q3-COLLECTOR C250-1
NET 'N00012' U2-2 R20-2 R19-1 C22-1
NET 'N00013' R150-2 U1-4 U1-7 U1-10 U1-14
NET 'N00013' R151-1
NET 'N00014' D1-ANODE J1-2 Q7-COLLECTOR
NET 'N00015' U3-18 TP_ICT6-1 R18-2
NET 'N00016' Q3-EMITTER R152-1
NET 'N00017' R1-2 R22-2 R20-1 R160-2 R157-2
NET 'N00017' R158-1 R161-1 R7-1 U2-14 U2-13
NET 'N00017' R163-2 R164-1 R25-2 R23-1
NET 'N00018' U3-17 TP_ICT5-1 R8-2
NET 'N00019' U3-9 R13-1
NET 'N00020' R13-2 Q7-BASE
NET 'N00021' Q7-EMITTER R11-1
NET 'N00022' J1-4 D2-ANODE
NET 'N00023' J1-5 D3-ANODE
NET 'N00024' R14-2 U3-6 SW1-NO
NET 'N00025' U1-6 Q2-COLLECTOR C251-1
NET 'N00026' U3-16 Y1-1 C20-1
NET 'N00027' U3-15 Y1-2 C19-1
NET 'N00028' C251-2 R160-1 U5-5
NET 'N00029' U5-7 R162-2 C254-2 C257-1
NET 'N00030' C257-2 R1-1 TP_ICT2-1 U2-5
NET 'N00031' U5-6 R161-2 R162-1 C254-1
NET 'N00032' U2-7 R6-2 C11-2 R8-1
NET 'N00033' U1-12 Q1-COLLECTOR C252-1
NET 'N00034' U2-6 R7-2 R6-1 C11-1
NET 'N00035' Q2-EMITTER R153-1
NET 'N00036' D2-CATHODE U4-2 D3-CATHODE C16-1
NET 'N00037' C252-2 R163-1 U5-10
NET 'N00038' R9-2 C21-1 U2-12 R10-1
NET 'N00039' U5-8 R165-2 C255-2 C258-1
NET 'N00040' C258-2 R25-1 TP_ICT3-1 U2-10
NET 'N00041' U5-9 R164-2 R165-1 C255-1
NET 'N00042' U2-8 R21-2 C23-2 R18-1
NET 'N00043' U2-9 R23-2 R21-1 C23-1
NET 'N00044' Q1-EMITTER R154-1
NET 'N00045' Q4-EMITTER R156-1
NET 'VCC' U4-4 C17-PLUS R9-1 R14-1 R11-2
NET 'VCC' U1-1 R150-1 U1-5 U1-11 R155-1
NET 'VCC' U2-4 U5-4 R15-1 U3-14 C18-1
NET 'AGND' TP_MEC1-1 TP_MEC2-1 TP_MEC3-1 TP_MEC4-1 R156-2
NET 'AGND' U5-12 U5-13 C17-MINUS R154-2 C21-2
NET 'AGND' R10-2 C16-2 U4-3 U4-1 SW1-COMMON
NET 'AGND' R153-2 U1-3 U1-8 U1-9 U1-13
NET 'AGND' R151-2 C19-2 C20-2 U3-2 U3-3
NET 'AGND' J1-1 J1-101 J1-102 R152-2 U2-11
NET 'AGND' U5-11 C18-2 U3-5
```

No	Description	Reference
1	Connector DF13-5-P-1.25H(20)	J1
2	Capacitor 470pF 50V Ceramic , 10%	C11,C22,C23,C253,C254,C255
3	Capacitor 3 3uF 10V Tantalum 20%	C17
4	Capacitor 22pF 50V Ceramic , 10%	C20,C19
5	Capacitor 68nF 25V Ceramic , 10%	C250,C251,C252,C256,C257,C258
6	Capacitor 220nF 25V Ceramic , 10%	C16,C18,C21
7	Diode 1N4148	D1,D2,D3
8	BarOn Motion Sensor, B3D - 1	U1
9	Op Am LMC6464AIM	U2,U5
10	Micro controller PIC16C42, 20 Mhz	U3
11	Resistor 1.2 Kohm, 1/16W, 5%	R8,R17,R18
12	Resistor 100KOhm,1/16W	R13,R14,R15,R158,R161,R164
13	Resistor 20KOhm,1/16W	R152,R153,R154,R156
14	Resistor 100Ohm,1/16W	R11
15	Resistor 10MOhm,1/10W	R1,R6,R9,R10,R19,R21,R22,R25,R151,R157,R159,R160,R162,R163,R165
16	Resistor 6.2KOhm,1/16W	R12
17	Resistor 4.7MOhm, 1/10W,	R150
18	Resistor 1MOhm,1/16W	R7,R20,R23
19	Resistor 390KOhm,1/16W	R155
20	Ultra Miniature Switch, DH-2C-C5-PA	SW1
21	Transistor 2N3906-PNP	Q7
22	Transistor MMBT5089-NPN	Q1,Q2,Q3,Q4
23	Volt Ref 5V, MIC5200	U4
24	Crystal, 6.144 MHz	Y1

APPENDIX C

CLAIMS

1. A secure computer system comprising:

at least one node connected to a communications network; and

a pen input device providing an output to said at least one node,

said node including handwriting recognition apparatus operative to receive the output of said pen and during substantially the entire duration of the data input from said pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of said pen and comparing said characteristics with reference characteristics, whereby successful communication is conditional on successful conversion of the output of the pen into writing characters.

2. A secure computer communications system comprising:

a communications network;

at least one terminal coupled to said communications network;

at least one server coupled to said communications network; and

a pen input device communicating via said at least one terminal with said server, and wherein

said server includes handwriting recognition apparatus operative to receive the output of said pen and during substantially the entire duration of the data input from said pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of said pen and comparing them with reference characteristics, whereby successful communication of information via said server is conditional on successful conversion of the output of the pen into

writing characters.

3. A secure computer communications system according to claim 2 and wherein communication from said pen input device to said server is secure by virtue of said communication being unintelligible in the absence of the availability of the reference characteristics.

4. A secure computer communications system according to claim 3 and wherein said server is located in a secure location.

5. A secure computer communications system according to claim 2 and wherein said pen input device comprises an accelerometer and provides accelerometer output signals to said terminal.

6. A secure computer communications system according to any of claims 2 - 5 and wherein said at least one terminal includes a display and is operative to provide visible indication of recognized symbols in response to an input from said server.

7. A secure computer communications system according to any of claims 2 - 6 and wherein said at least one terminal includes a keyboard for the input of function commands.

8. A system according to any of the preceding claims and wherein information input by the pen input device, when and only when successfully recognized, is communicated to a utilization device.

9. A system according to any of the preceding claims and wherein said characteristics of the handwriting of the user comprise a mapping of hand movements, and

wherein said reference characteristics comprise a reference mapping of hand movements for said user.

10. A system according to claim 9 and wherein said reference mapping comprises a mapping of hand movements to characters for said user.

11. A system according to any of the preceding claims and wherein said successful communication is not conditional on any other user input in order to achieve security.

12. A system according to any of the preceding claims and wherein said successful communication is not conditional on use of any additional system resources in order to achieve security.

13. A method for providing a secure computer system, the method comprising:

providing at least one node connected to a communications network; and

providing a pen input device providing an output to said at least one node,

said node including handwriting recognition apparatus operative to receive the output of said pen and during substantially the entire duration of the data input from said pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of said pen and comparing said characteristics with reference characteristics, whereby successful communication is conditional on successful conversion of the output of the pen into writing characters.

14. A method for providing a secure computer communications system, the method comprising:

providing a communications network;

providing at least one terminal coupled to said communications network;

providing at least one server coupled to said communications network; and

providing a pen input device communicating via said at least one terminal with said server, and wherein

said server includes handwriting recognition apparatus operative to receive the output of said pen and during substantially the entire duration of the data input from said pen to convert the output of the pen into writing characters, by recognizing the characteristics of the handwriting of a user of said pen and comparing them with reference characteristics, whereby successful communication of information via said server is conditional on successful conversion of the output of the pen into writing characters.

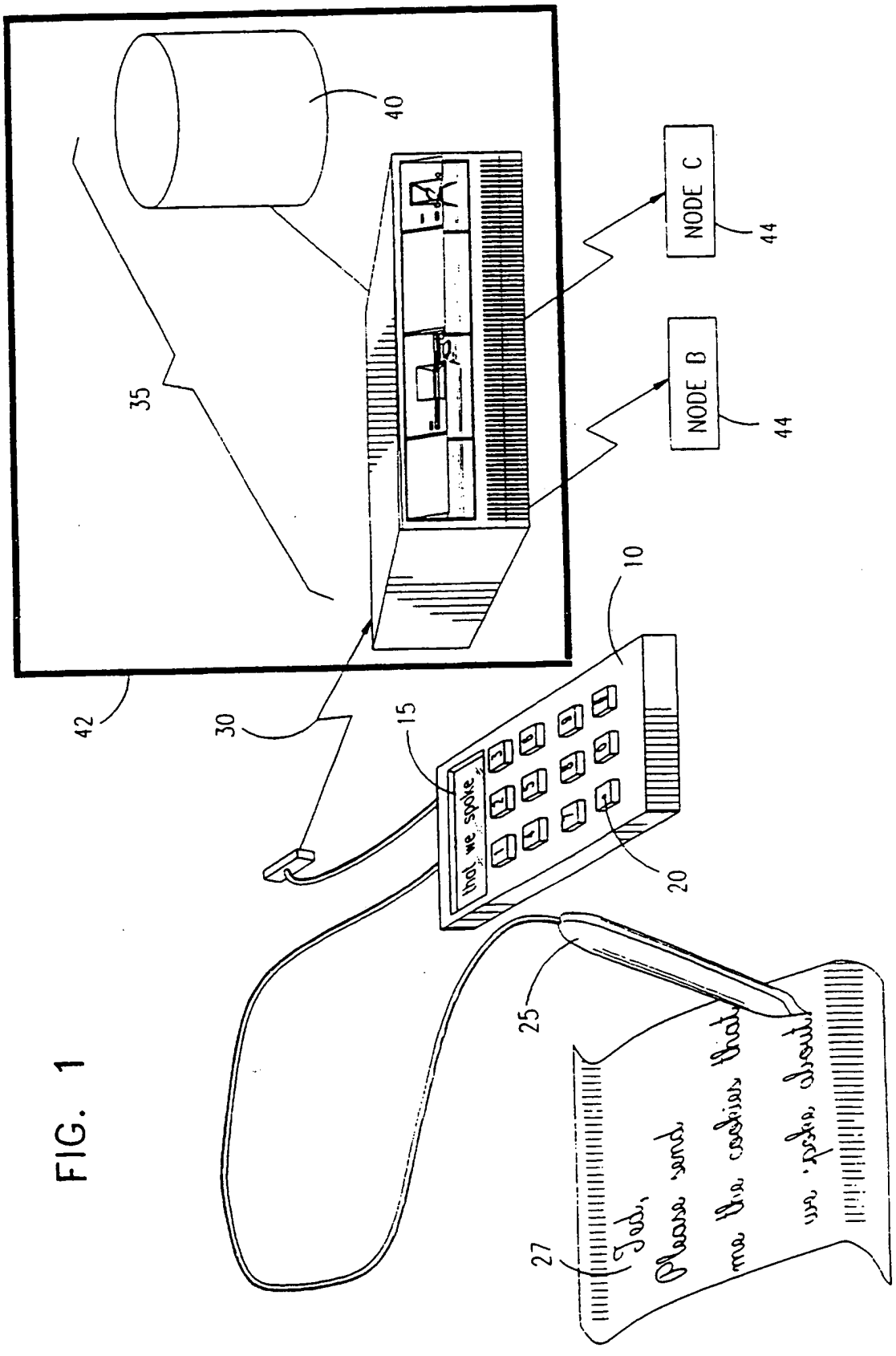
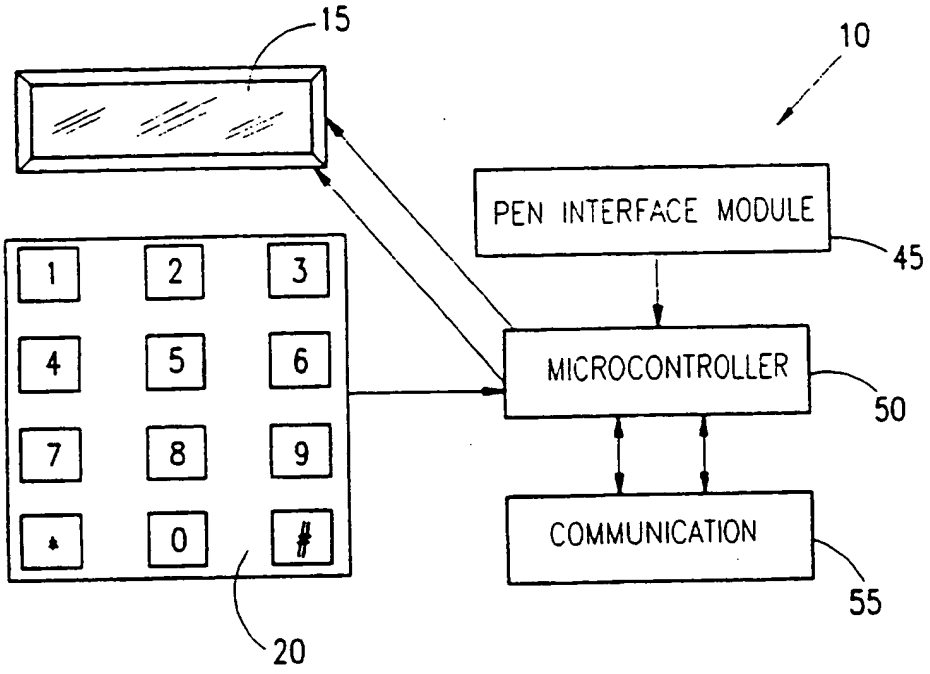

40
35
42
30
15
10
20
25
27
NODE C
44
NODE B
44
Hal, we spoke
Jeb,
Please send
me the cookies that
we spoke about

FIG. 1

FIG. 2


15
10
PEN INTERFACE MODULE
45
1
2
3
4
5
6
MICROCONTROLLER
50
7
8
9
*
0
#
COMMUNICATION
55
20

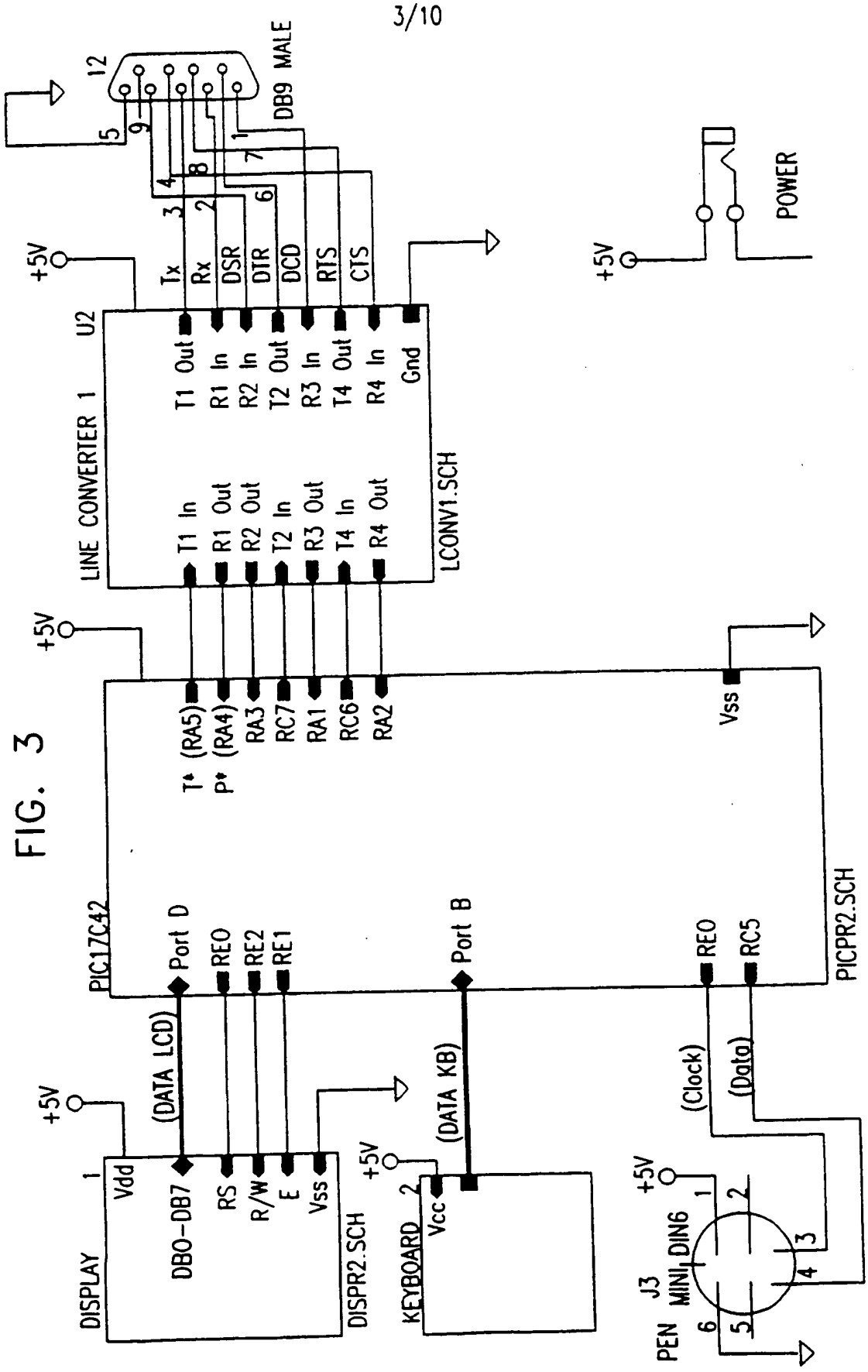

J2
DB9 MALE
5
9
1
4
8
7
3
2
6
Tx
Rx
DSR
DTR
DCD
RTS
CTS
+5V
POWER
U2
LINE CONVERTER 1
T1 Out
R1 In
R2 In
T2 Out
R3 In
T4 Out
R4 In
Gnd
T1 In
R1 Out
R2 Out
T2 In
R3 Out
T4 In
R4 Out
LCONV1.SCH
T* (RA5)
P* (RA4)
RA3
RC7
RA1
RC6
RA2
Vss
PIC17C42
Port D
RE0
RE2
RE1
Port B
RE0
RC5
PICPR2.SCH
(DATA LCD)
(DATA KB)
(Clock)
(Data)
DISPLAY
Vdd
DB0-DB7
RS
R/W
E
Vss
DISPR2.SCH
KEYBOARD
Vcc
J3
MINI DIN6
PEN

FIG. 3

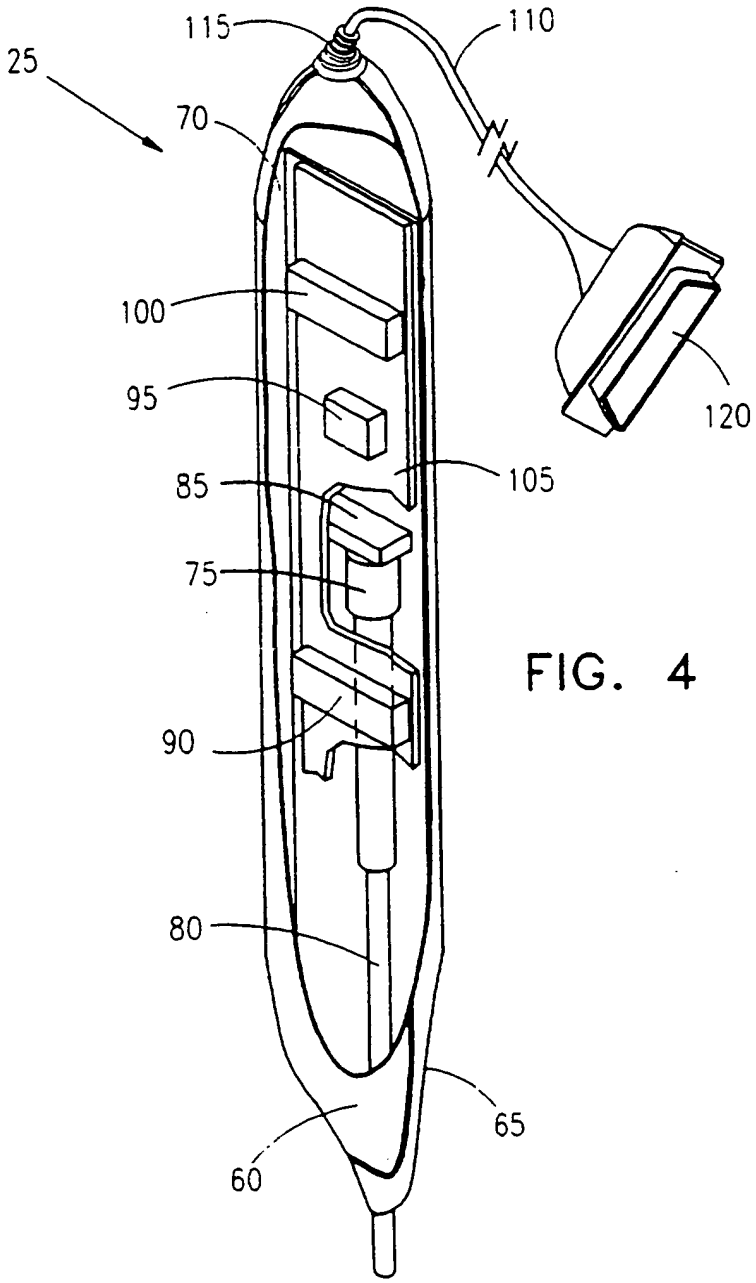


FIG. 4

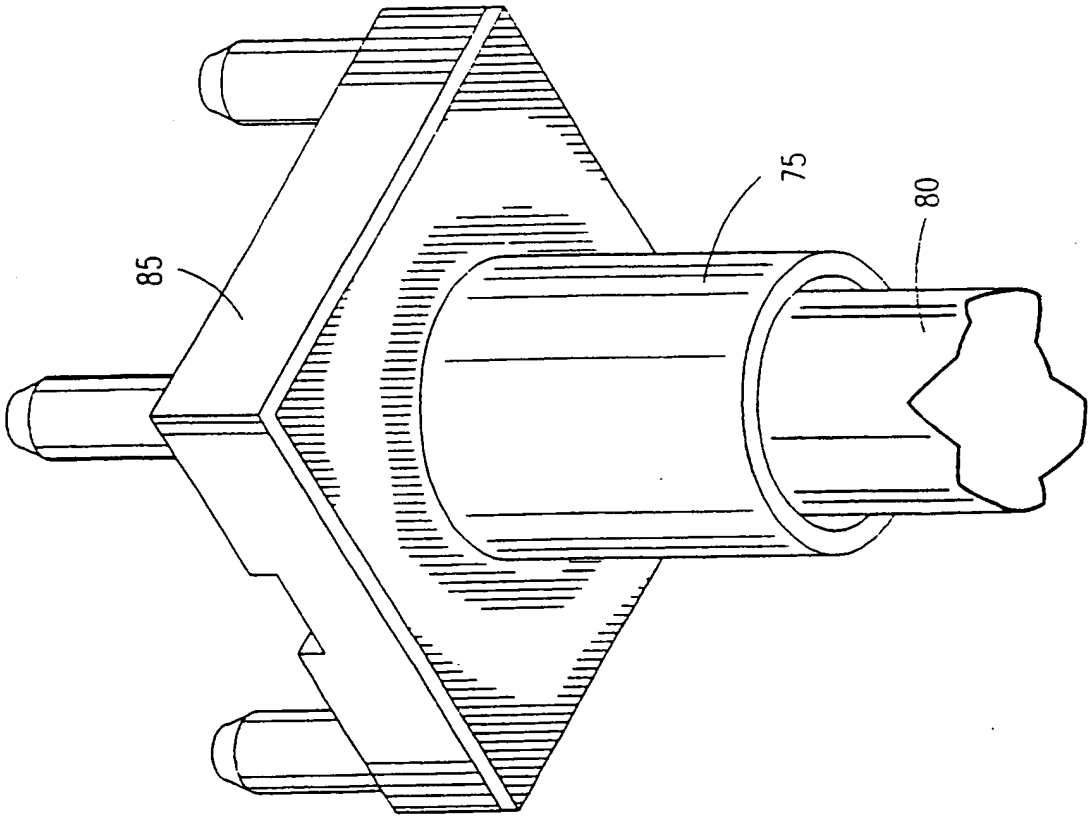


FIG. 5A

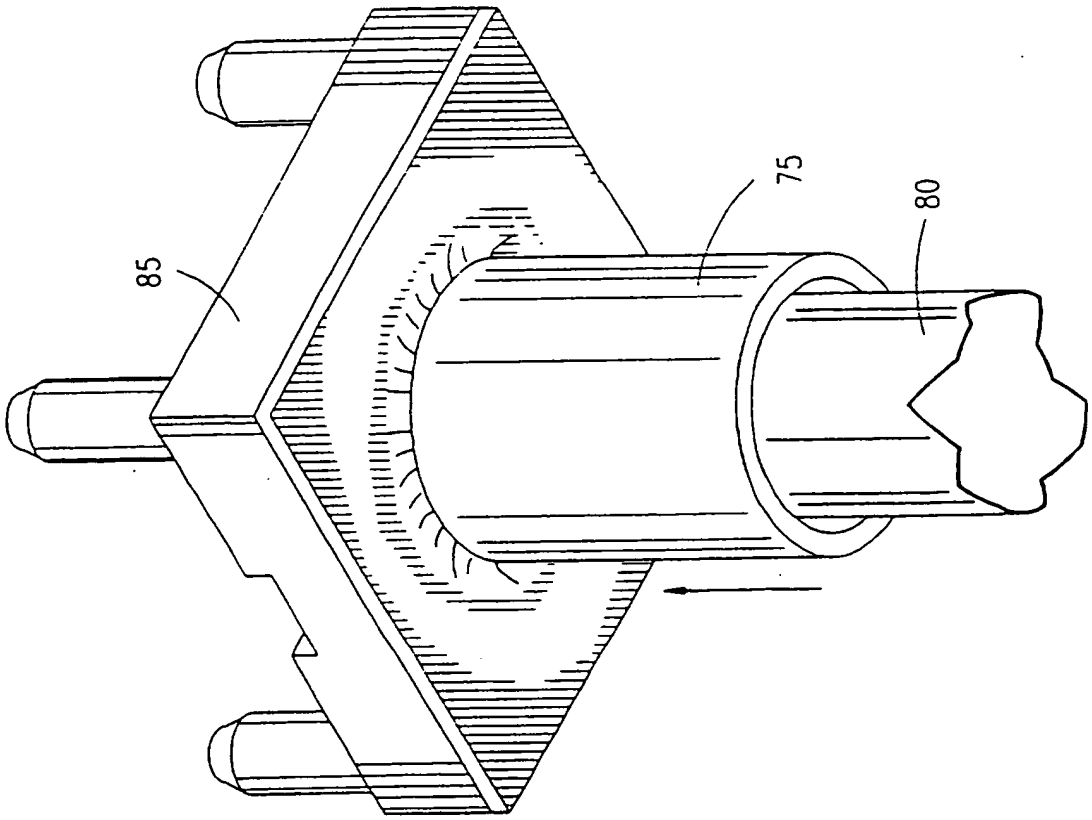


FIG. 5B

FIG. 6

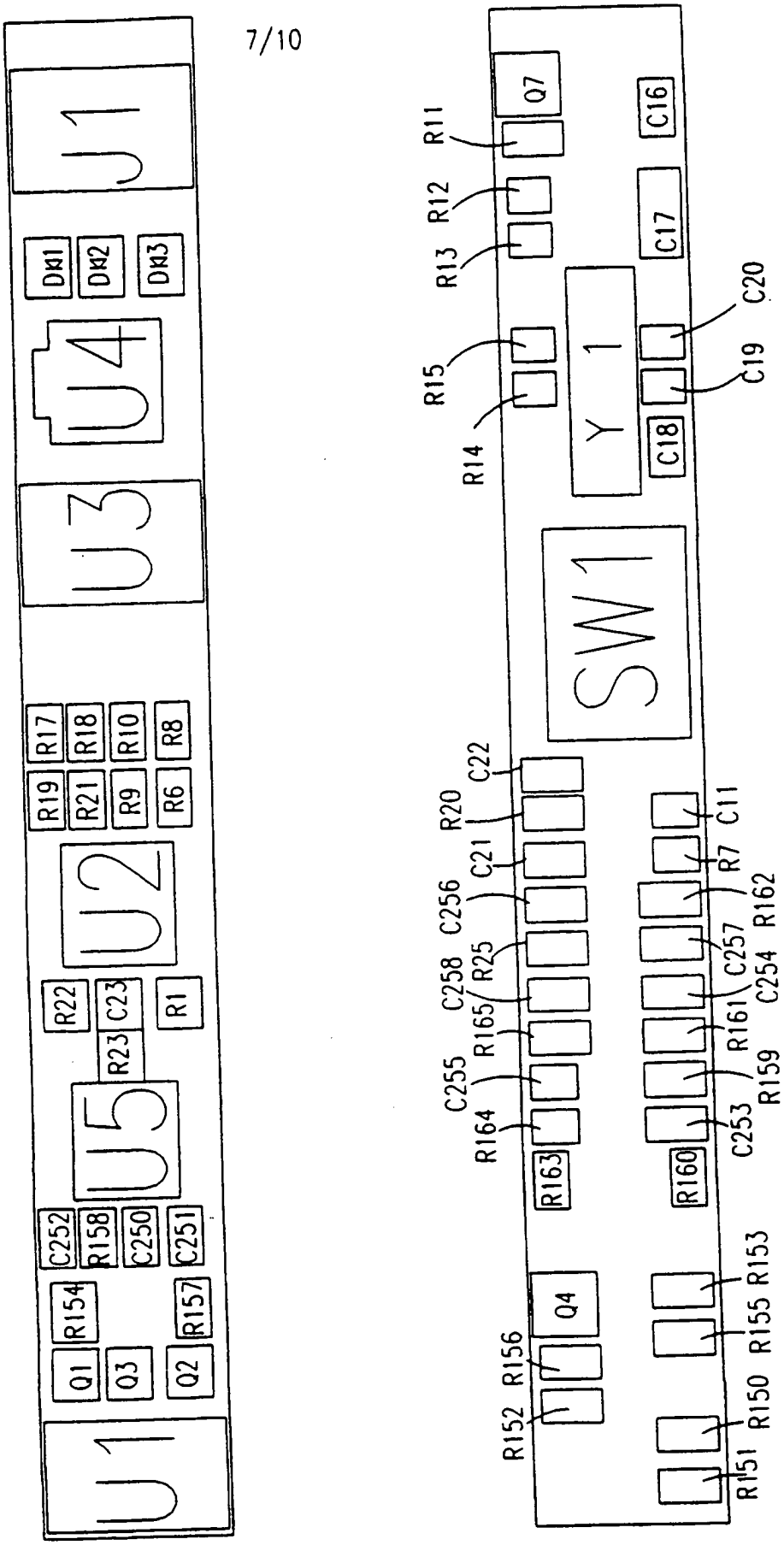
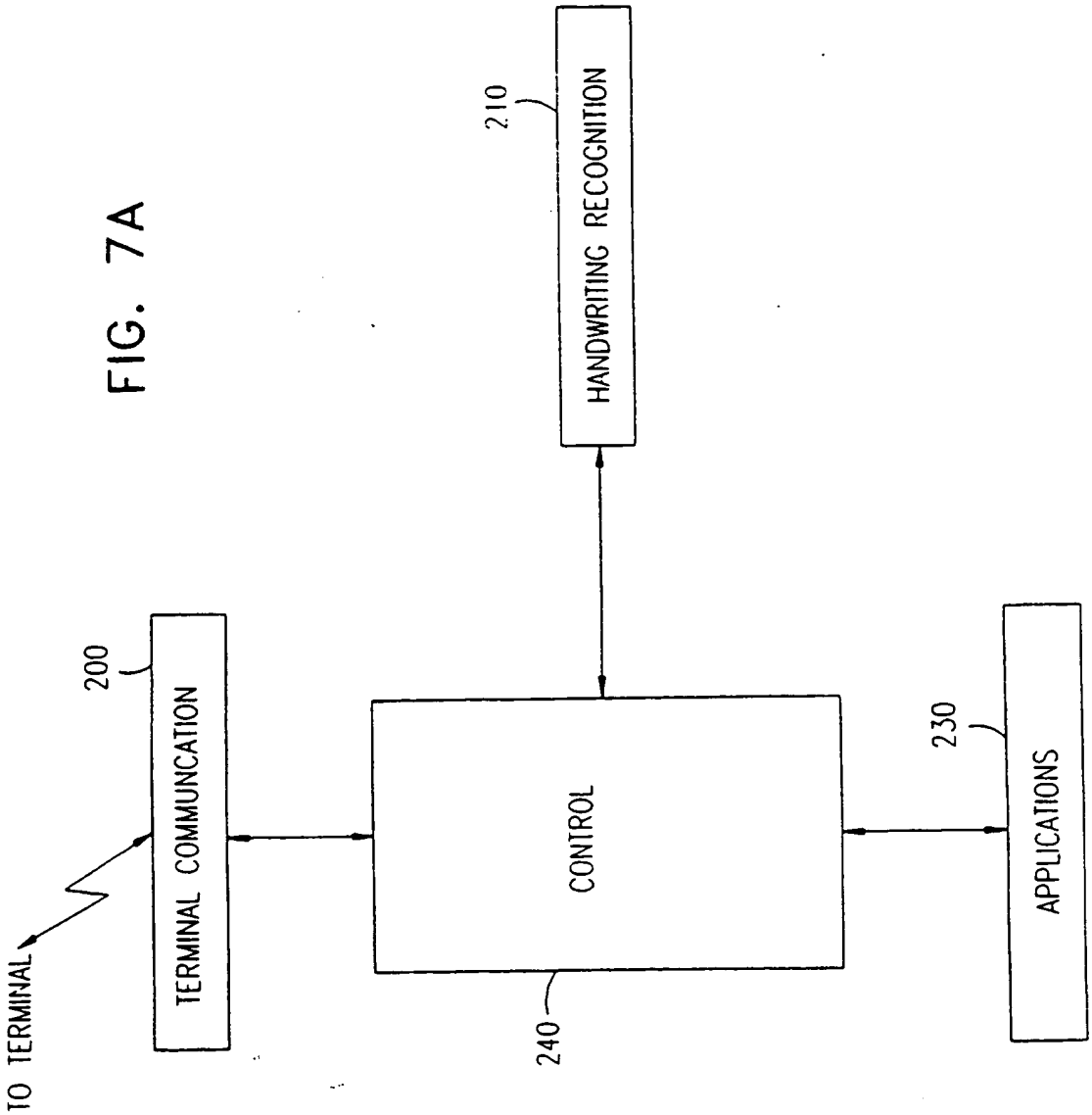

U1
U2
U3
U4
U5
SW1
Y1
Q1
Q2
Q3
Q4
Q7
DW1
DW2
DW3
R1
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R17
R18
R19
R20
R21
R22
R23
R25
R150
R151
R152
R153
R154
R155
R156
R157
R158
R159
R160
R161
R162
R163
R164
R165
C11
C16
C17
C18
C19
C20
C21
C22
C23
C250
C251
C252
C253
C254
C255
C256
C257
C258

FIG. 7A


HANDWRITING RECOGNITION
210
TERMINAL COMMUNICATION
200
CONTROL
240
APPLICATIONS
230
TO TERMINAL

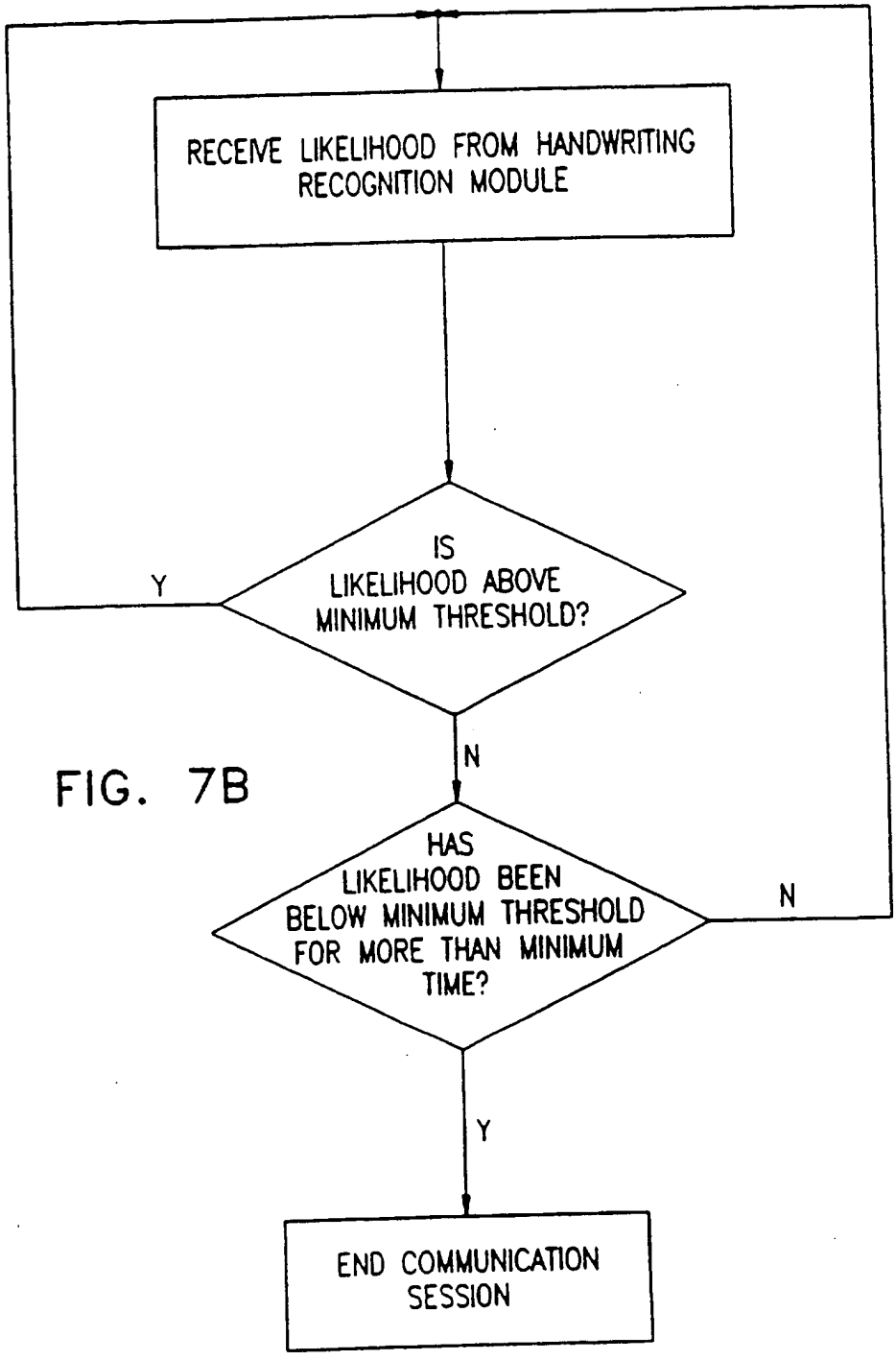

RECEIVE LIKELIHOOD FROM HANDWRITING RECOGNITION MODULE
IS LIKELIHOOD ABOVE MINIMUM THRESHOLD?
Y
N
HAS LIKELIHOOD BEEN BELOW MINIMUM THRESHOLD FOR MORE THAN MINIMUM TIME?
N
Y
END COMMUNICATION SESSION

FIG. 7B

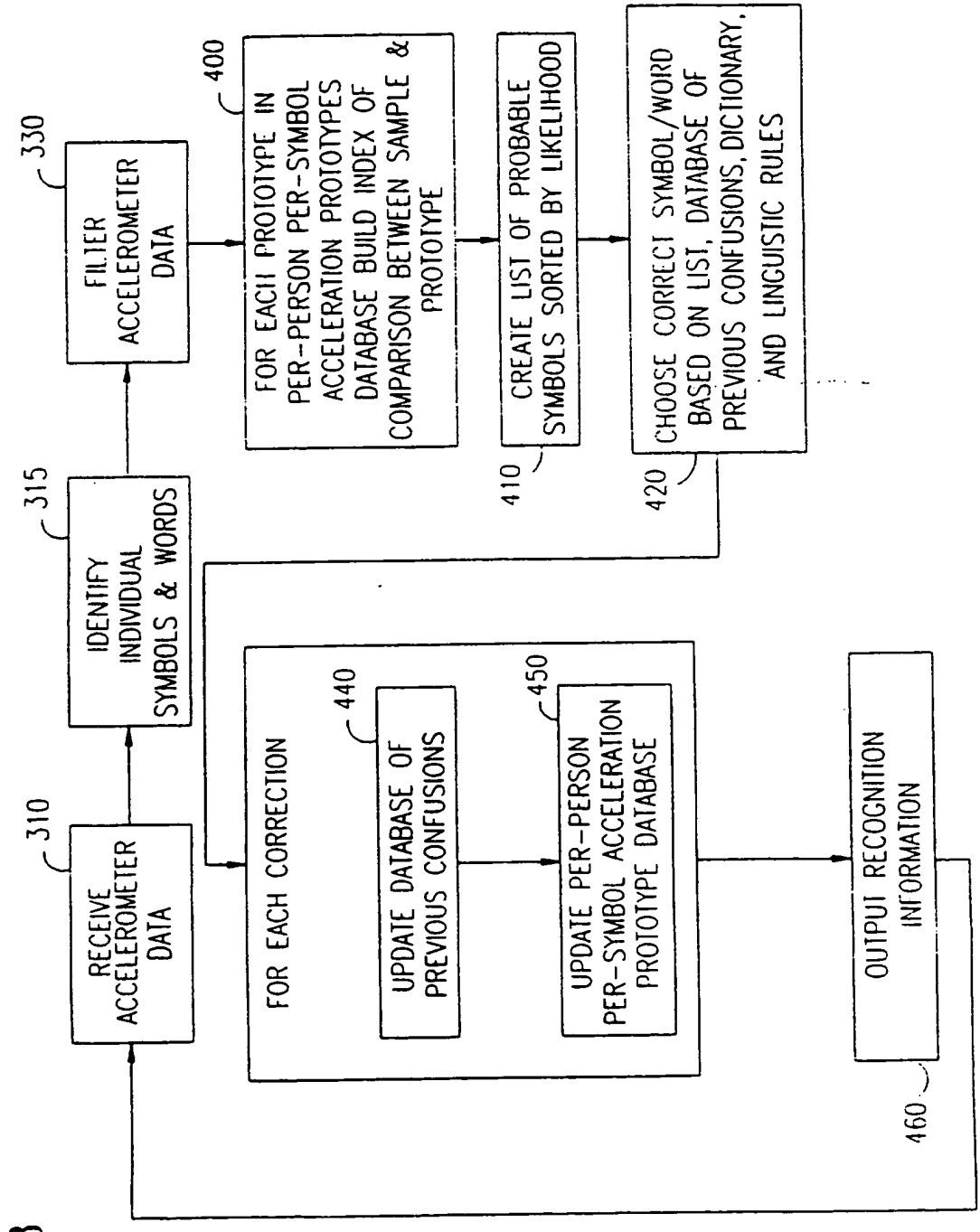

RECEIVE ACCELEROMETER DATA
310
IDENTIFY INDIVIDUAL SYMBOLS & WORDS
315
FILTER ACCELEROMETER DATA
330
FOR EACH PROTOTYPE IN PER-PERSON PER-SYMBOL ACCELERATION PROTOTYPES DATABASE BUILD INDEX OF COMPARISON BETWEEN SAMPLE & PROTOTYPE
400
CREATE LIST OF PROBABLE SYMBOLS SORTED BY LIKELIHOOD
410
CHOOSE CORRECT SYMBOL/WORD BASED ON LIST, DATABASE OF PREVIOUS CONFUSIONS, DICTIONARY, AND LINGUISTIC RULES
420
FOR EACH CORRECTION
UPDATE DATABASE OF PREVIOUS CONFUSIONS
440
UPDATE PER-PERSON PER-SYMBOL ACCELERATION PROTOTYPE DATABASE
450
OUTPUT RECOGNITION INFORMATION
460

FIG. 8